CHAPTER 5
LAND DISPOSAL/LAND TREATMENT OPTIONS

5-1. Introduction

a. This chapter of the manual presents a general discussion of landfills, surface impoundments, land treatment, deep well injection and waste piles with respect to:

- Wastes Suitable for Disposal
- Limitations of Each Disposal Option
- Disposal Procedures
- Design Elements
- Equipment

b. The treatment of each of these topics is brief, focusing on the needs of the design engineer. Where appropriate, reference has been made to source documents for additional information on these topics. With respect to design elements, this chapter summarizes the elements required for each of the five disposal options at Army installations. Since these elements constitute the key design tools for meeting RCRA requirements for hazardous waste land treatment/disposal facilities, they are treated in detail in chapter 6.

c. Table 5-1 lists the design elements required for DA land disposal/land treatment facilities and refers to the sections of the manual where these are discussed in detail. Figure 5-1 presents a conceptual layout of a hazardous waste facility master plan with landfill, surface impoundment, land treatment, and waste pile units.

d. The design engineer should be familiar with closure requirements for a given unit; therefore, these are included in this chapter for each disposal option under the section on Design Elements. Closure standards, mandated by 40 CFR 264, subpart G, are designed to extend protection of human health and the environment beyond the active life of a facility.

e. As defined by RCRA, each of the disposal options has characteristics that distinguishes it from the others; however, as noted below, some overlapping in definition occurs with landfills and surface impoundments. The RCRA definitions of these five disposal options are summarized below.

(1) A landfill is defined in 40 CFR 260.10 as a disposal facility or part of a facility where hazardous waste in bulk or containerized form is placed in or on land, typically in excavated trenches or cells. However, DA hazardous waste landfills must not accept bulk liquids or sludges with leachable liquids.

(2) A surface impoundment, according to 40 CFR 262.10, is a facility (or part of a facility) that is a natural topographic depression, man-made excavation, or diked area formed primarily of earthen materials (although it may be lined with man-made materials) designed to hold an accumulation of liquid wastes or wastes containing free liquid. According to this definition, a surface impoundment is assumed to have a fluid surface and hold non-containerized free bulk liquids. Examples of surface impoundments are holding, storage, settling, and aeration pits, ponds, and lagoons. Surface impoundments can be classified as disposal, storage or treatment facilities, as follows:

Table 5-1. Design Features Required by RCRA For DA Land Disposal/land Treatment Facilities [a]

Facility Elements	Reference [b]	Disposal/Land Treatment Facilities			
		Surface Impoundments	Waste Piles	Land Treatment	Landfills
Liner System C	6-3	Required	Required	NA	Required
Leak Detection System	6-4	Required	Required	NA	Required
Monitoring Wells	8-3	Required	Required	Required	Required
Leachate Collection and Removal Systems	6-4	NA	Required	NA	Required
Run-on/Run-off Controls	6-5	Required	Required	Required	Required
Wind Dispersal Controls	6-8	NA	Required	Required	Required
Overtopping Controls	6-8	Required	NA	NA	NA
Cap (Final Cover)	6-7	Required (disposal)	NA	NA	Required
Closure and Post-Closure Care	5-2, 5-3, 5-4	Required (disposal)	NA	Required	Required

[a] Injection wells are excluded from this table since their design features are unique. See paragraph 5-5 of this manual.
[b] Paragraph(s) in this TM describing the design feature.
[c] Double liners are required at all DA installations unless a waiver is obtained from HQ, (DAEN-ECE-G), Washington, DC 20314
US Army Corps of Engineers.

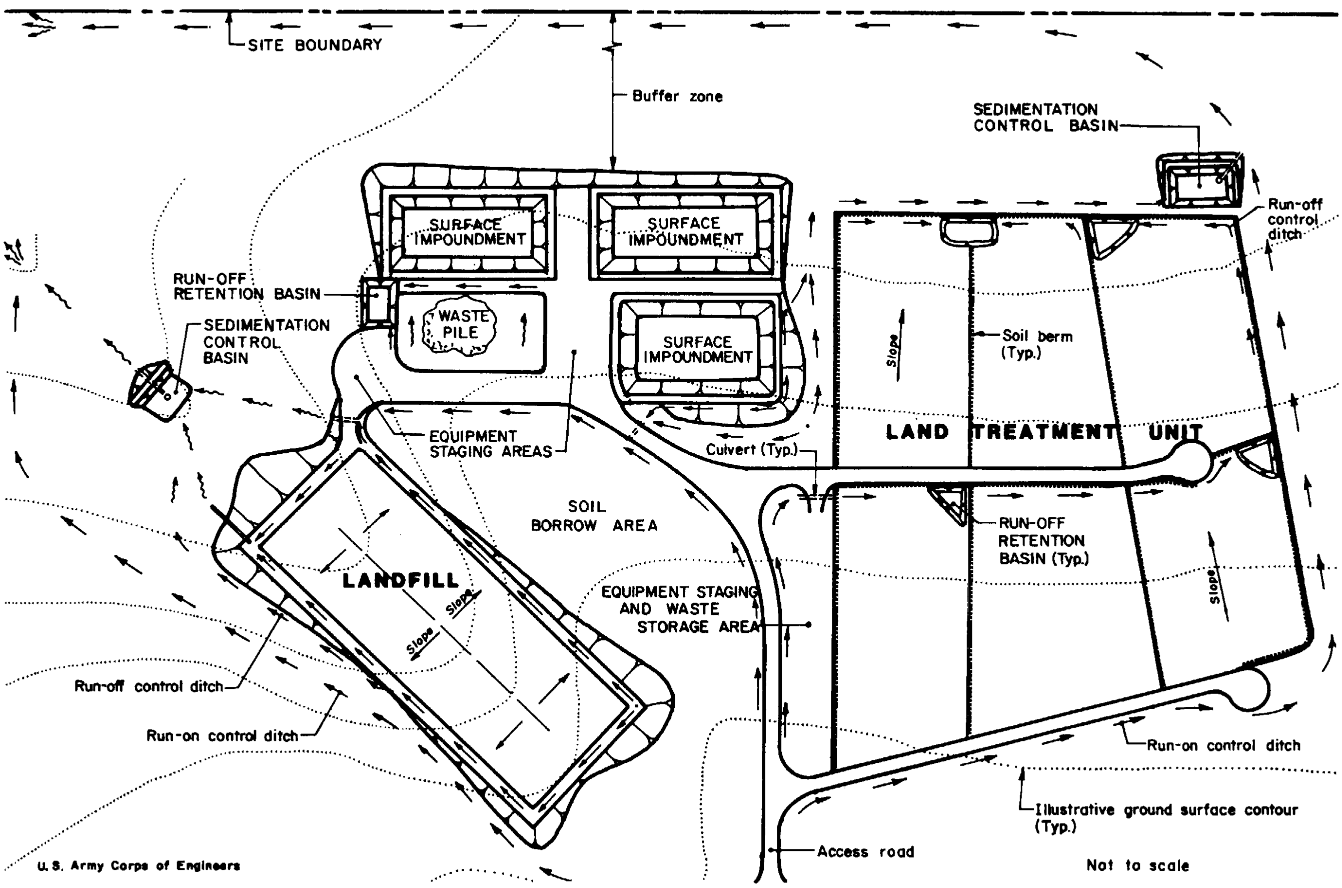

Figure 5-1. Illustrative hazardous waste master plan.

(a) Disposal-Hazardous wastes remain after closure.

(b) Storage-Wastes are held for a temporary period and removed at closure.

(c) Treatment-Wastes are modified physically or chemically to render them less toxic, mobile, or otherwise less hazardous.

(3) A land treatment unit is a facility or part of a facility at which hazardous waste is applied onto or incorporated into the soil surface. As provided in 40 CFR 264, subpart M, a waste must not be land treated unless the hazardous constituents in the waste can be degraded, transformed or immobilized in the treatment zone (ranging up to 5 feet in depth). Units designed primarily for the purpose of dewatering without treatment are considered surface impoundments rather than land treatment units. Land treatment units are unlike other land disposal units in that they are not designed and operated to minimize all releases to ground-water; rather, they are open systems that allow liquids to move out of the unit.

(4) Underground injection is the subsurface emplacement of fluids through a bored, drilled, or driven well, or through a dug well, wherein the depth of the dug well is greater than the largest surface dimension. Septic tanks or cesspools used to dispose of hazardous waste have been specifically included in the RCRA definition of injection well.

(5) A waste pile is any non-containerized accumulation of solid, non-flowing hazardous waste that is used for treatment or storage; however, waste piles may not be used to intentionally dispose of wastes. If the owner or operator of a waste pile wishes to dispose of wastes, he must apply for a landfill permit and manage the pile as a landfill. Piles are generally small, and many are in buildings or maintained outside on concrete or other pads. They are frequently used to accumulate waste before shipment, treatment, or disposal and are typically composed of a single dry material.

5-2. Landfills

a. Suitable wastes. The primary restriction on landfilling of hazardous wastes is the elimination of liquid disposal. Bulk liquids or sludges with leachable liquids must not be landfilled at DA hazardous waste facilities; disposal of such wastes will be permitted only in surface impoundments. RCRA regulations permit disposal of small quantities of liquids in small containers in an overpack drum (lab pack), provided that the latter contains sufficient absorbent material to absorb all of the liquid contents of the inside containers. The inside containers must be non-leaking and compatible with the contained waste. The overpack drum must be an open head DOT-specification metal shipping container of no more than 110-gallon capacity. Batteries, capacitors or similar non-storage containers which contain free liquids may not be landfilled. Acutely hazardous wastes such as carcinogens must be solidified prior to disposal, regardless of their quantities.

b. Disposal constraints. Landfills should be sited in a hydrogeologic setting that provides maximum isolation of the waste from ground-water. This is achieved by vertical separation of wastes from the uppermost ground-water, and low permeability of the subsurface material providing the hydraulic separation. In addition, the landfill must be located above the 100-year flood level and not interfere with major surface drainage.

(1) Ideally, the soils in the area should be suitable for daily cover as well as final cover. In cold regions where frost penetration is significant (3 to 6 feet), the cover material should be stockpiled and maintained in as dry a condition as possible to facilitate wintertime operations.

(2) Location of landfills in karst terrain (or similar geologic formations) and in seismic zones 3 and 4 (as defined in TM 5-809-10) should be avoided whenever possible. However, if landfills are sited in such areas, the following precautions should be taken:

(a) An extensive geological investigation must be performed to ensure that the facility is not located on or in the near vicinity of sink holes or caverns and that the soil and rock in the area are suitable for location of this type of facility.

(b) After the final site selection has been completed, USACE (DAEN-ECE-G) shall be notified of proposed location and geological conditions. This notification shall be made a minimum of 30 days before design begins.

c. Procedures. Disposal by landfilling involves placement of wastes in a secure containment system that consists of double liners, a leak detection system, a leachate collection system and final cover. Wastes delivered to the landfill are unloaded by forklift or front-end loaders and placed in the active waste lift. Hazardous materials shall be segregated in cells or subcells according to physical and chemical characteristics to prevent mixing of incompatible wastes. Following their placement, the hazardous wastes are covered with sufficient soil to prevent wind dispersal. Successive lifts are placed and the cover soil graded so that any direct precipitation is collected in a sump. All direct precipitation collected in the sump is tested for contamination. As filling continues, wastes are placed so as to direct any run off toward a temporary sump at the lower segment of the base liner. For operations during extremely wet conditions, tarps may be used to cover the active area to minimize infiltration of rainfall. In high rainfall regions, semi-permanent roof/rainfall protection can be installed over the entire cell using either rigid or stress-tensioned structures

The structure should be designed to prevent all rainfall from entering the cell until final cover is completed; then it is dismantled and erected over the next cell. Another alternative to operations during extremely wet weather is to containerize or store wastes until the rainfall season is over. As areas of the secure landfill are filled to final grade, a final soil cover is installed in accordance with the facility's operation plan. Figure 5-2 illustrates a typical landfill operations plan.

d. The major design elements of hazardous wastes landfills, discussed in detail in chapter 6, are:

- Double liners
- A leak detection system between the liners
- A leachate collection and removal system above the liner
- Run-on and run-off control systems
- A final cover to minimize infiltration of precipitation into the closed landfill

(1) The base liner system is designed and constructed to prevent migration of wastes during the active life of the disposal unit into the liner, and out of the landfill into subsurface soil, ground-water or surface water. A leak detection system between the double liners enables the detection and removal of any seepage, and evaluation of liner performance.

(2) Located above the double liners is the leachate collection and removal system, which consists of slotted drainage pipes designed to collect leachate that flows under the influence of gravity to low points within the landfill. The leachate collection and removal system must be designed and operated to ensure that the depth of leachate over the liner does not exceed 1 foot.

e. Closure. Closure of a landfill is achieved by installing a final cover which has a permeability less than or equal to that of the bottom liner. The cover should be capable of (1) minimizing infiltration of liquids, (2) functioning with minimum maintenance, (3) promoting drainage and minimizing erosion of cover, and (4) accommodating settling and subsidence.

f. Equipment needs. Secure landfills require equipment for (1) handling wastes and cover material, (2) performing support functions, (3) spill and fire control, and (4) decontamination. For waste handling, a forklift and a front-end loader are typically used to unload and place containers and solid materials in assigned active waste lifts. Dozers and self-loading scrapers are used to spread and compact cover material. For grading final surfaces, the crawler dozer is effective; it can economically doze earth over distances up to 300 feet. Scrapers can haul cover material economically over relatively long distances (more than 1, 000 feet). Since construction equipment is heavy when loaded, precautions must be taken in placing initial lifts of wastes over the base liner. Subsequent lifts of bulk wastes and soil cover should be consolidated by compactors to minimize settlement.

(1) Support equipment for a secure landfill may include a road grader, water truck, pickup trucks and vacuum trucks. The road grader can be used to maintain dirt and gravel roads on the site, to grade the soil cover, and to maintain any unlined drainage channels surrounding the fill. Water trucks range from converted tank trucks to highly specialized, heavy vehicles that are generally used in road construction operations. They are used at the landfill for construction, to control dust, and if necessary, fight fires.

(2) In accordance with 40 CFR 264.32, all facilities must be equipped with communication or alarm systems, fire control equipment, spill control equipment, and decontamination equipment (unless an exemption is obtained from the EPA Regional Administrator [RA]). Paragraph 7-1 describes procedures and equipment required for facility contingency plans.

(3) All equipment used to unload and place wastes must be decontaminated before being taken out of the disposal operation and staging area. Incoming vehicles not used in the unloading operation should be restricted to staging areas, or clean soil areas within the landfill.

5-3. Surface Impoundments

a. Wastes suitable for impoundments. Surface impoundments are used for the evaporation and treatment of bulk aqueous wastes. Typical DA wastes which would be considered appropriate for impoundments include waste acids and rinse water with traces of propellant. Reactive wastes must not be placed in a surface impoundment unless they are made nonreactive and defined in 40 CFR 261.23. Since mixing of wastes is inherent in a surface impoundment, incompatible wastes should not be placed in the same impoundment. The potential dangers from the mixing of incompatible wastes include extreme heat, fire, explosion, violent reaction, production of toxic mists, fumes, dusts, or gases, and damage to the structural integrity of the surface impoundment. Clearly the potential inpacts on human health or the environment which could result from such conditions must be avoided.

b. Disposal constraints. Surface impoundments should be located in a hydrogeologic setting that limits vertical and horizontal hydraulic continuity with ground-water. Surface impoundments should be sited and designed with maximum protection of groundwater provided by liners, and low-permeability underlying soils. The hydraulic head formed in the impoundment provides for a high potential for liquid seepage and subsurface migration. The precautions concerning location of landfills in karst terrain or seismic zones 3 and 4 also pertain to surface impoundments (see para 5-2b(2)).

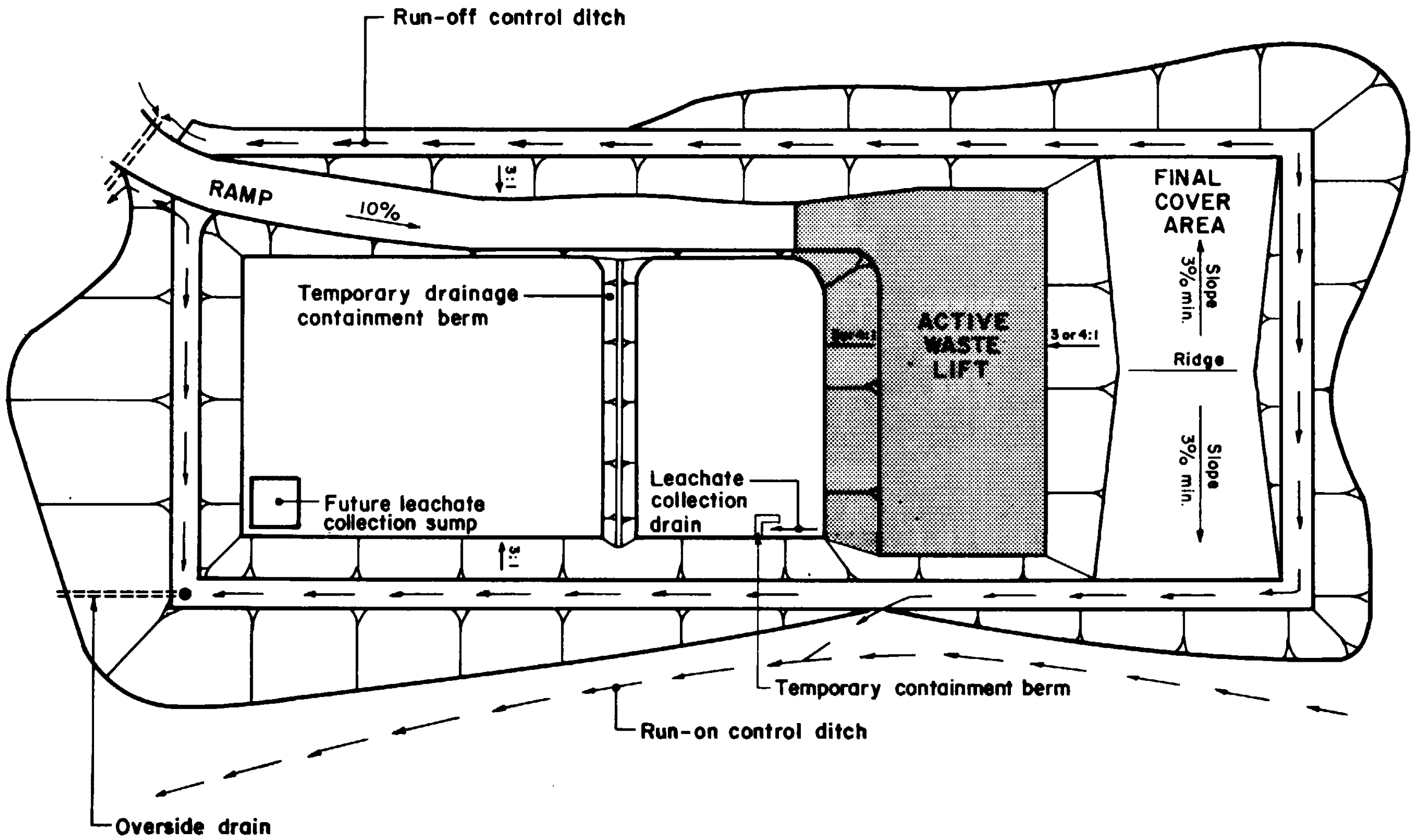

Figure 5-2. Landfill operations plan.

c. Procedures. Impoundment of hazardous waste involves disposing of liquid wastes in a man-made excavation or diked area that ranges in surface area from tenths to hundreds of acres. Wastes are typically delivered to the impoundment by pipe systems or bulk tankers which offload into the impoundment at a "discharge apron."

(1) During the time that the liquid wastes are impounded, operations include, but are not limited to, the following inspection activities:

- Monitoring to ensure that liquids do not rise into the freeboard (prevention of overtopping)
- Inspecting containment berms for signs of leakage or erosion
- Periodic sampling, if needed, of the impounded wastes for selected chemical parameters
- Inspecting periodically for floral and faunal activities (such as animal burrows) that could cause leaks through earthen dikes, levees or embankments
- Monitoring of leak detection systems

(2) The major operations at an impoundment involve "removal" of the liquid waste. There are a number of different methods for removing liquid wastes; each method must be implemented in accordance with the standards described in this manual. Waste removal methods include:

(a) Decanting-Liquids within or ponded on the surface of the impoundment can be removed by gravity flow or pumping to a treatment facility if there is not a large percentage of settleable solids.

(b) Pumping and settling-Liquids or slurries composed of suspended or partially suspended solids can be removed by pumping into a lined settling pond and then decanting. Sludges are disposed of in a dry state, and either returned to the impoundment or disposed of in another contained site.

(c) Solar drying-Liquids are removed by evaporation; sludges remaining after evaporation are left in the impoundment or disposed of in another contained site. Note that volatile organics shall not be handled in this manner.

(d) Chemical neutralization-Aqueous waste with low levels of hazardous constituents frequently lends itself to chemical neutralization and subsequent normal discharge under NPDES permit requirements.

(e) Infiltration-Certain aqueous waste can be handled by infiltration through soil, provided that the hazardous substances are removed by either soil attenuation or underdrain collection of the solute. Collected solutes are usually treated.

(f) Process reuse-Some aqueous waste can be recycled in the manufacturing process a number of times until the contaminants are at a level requiring disposal by one of the methods previously mentioned. Reuse does not dispose of the waste but can significantly reduce the quantities requiring disposal.

(g) Addition of Absorbents-Materials can be added to aqueous impounded wastes to absorb free liquids. Absorbents include fly ash, kiln dust and commercially available sorbents. The designer should avoid selecting biodegradable absorbents such as straw or rice, since they can decompose, resulting in the formation of landfill gas, or contribute to void space, which might lead to subsidence.

(3) Cleaning and closure processes normally involve removal of waste residuals from the impoundment. Removal methods for settled residues and contaminated soil include removal of the sediment as a slurry by hydraulic dredging; excavation of the sediments with a jet of high-pressure water or air; vacuum transport of powdery sediments; or excavation of hard solidified sediments by either dragline, front-end loader or bulldozer. Sediments removed by one of these methods may require dewatering to comply with EPA guidelines for disposal.

(4) When residual wastes will be left in the impoundment at closure (e.g., the impoundment is used for disposal), the wastes must be stabilized to a bearing capacity sufficient to support the final cover. Typically, stabilization is achieved by either passive (evaporation) or active dewatering. Active processes, including mechanical dewatering or thermal drying, are described in EPA SW-873.

d. Design elements. Basic design requirements for surface impoundments mandated by 40 CFR 264 include:

(1) Double liners with a leak detection system and monitoring wells to prevent wastes from migrating into subsurface soil and ground water and surface water during the active life of the site (see figures 6-2 and 6-5).

(2) Prevention of overtopping the sides of the impoundment.

(3) Construction specifications that ensure the structural integrity of dikes.

e. Closure. As specified in 40 CFR 264, a surface impoundment can be closed in one of two ways: (1) Removing or decontaminating all wastes, waste residues, system components (such as liners), subsoils and structures or equipment. No post-closure care is required as long as removal or decontamination is complete.

(2) Removing liquid waste or solidifying the remaining waste. A final cover will be placed over the closed impoundment. Post-closure care will consist of monitoring ground-water and conducting corrective action if it is warranted (see para 8-5), and maintaining the effectiveness of the final cover. For a doublelined disposal unit, the leak detection system will be monitored as part of post-closure care.

f. Equipment needs. Equipment for surface impoundments includes that needed for

- Removal of liquid from the impoundment.
- Removal of settled residuals and contaminated soil.
- Dewatering sediments prior to their final disposal.
- Solidification and stabilization of residual wastes.

(1) At the time of closure, impounded liquid can be removed by a number of methods described in paragraph 5-3c; typical equipment used for this purpose is a centrifugal pump or a hydraulic pipeline dredge. Waste residuals can be removed by means of a vacuum truck to pump slurried sediment from the impoundment, a rotary cutter to remove hardened sediments that do not flow freely, or a dragline or front-end loader to excavate hard, solidified sediments. To dewater sediments, filter presses may be used to produce a nonflowable solid.

(2) Any equipment used for liquid sediment removal or dewatering must be decontaminated before being taken out of the disposal operation area.

5-4. Land Treatment

a. Suitable Wastes. Land treatment is potentially a cost-effective method of disposing of industrial wastes such as bulk organic sludges that have a high water content. A variety of industrial wastes, effluents, sludges and solid wastes are suitable for treatment and disposal by the land treatment method, including those containing or derived from hazardous constituents listed in appendix VIII of 40 CFR 261. However, for wastes that contain very high concentrations of toxic organics, a disposal method other than land treatment is required.

(1) Hazardous waste land treatment facilities must include plans for conducting a treatment demonstration and reporting the complete demonstration results. The objective of the demonstration is to establish the operating practices that will completely degrade, transform or immobilize hazardous constituents. Regardless of the demonstration method selected, the following criteria must be met:

- Accurate simulation of the characteristics and operating conditions of the proposed treatment unit, including
  -waste characteristics
  -climate in the area
  -regional topography
  -soil characteristics and depth of the treatment zone
  -operating practices to be used
- Complete degradation, transformation, or immobilization in the treatment zone of the hazardous constituents in the waste
- Operation of the land treatment unit in a manner that protects human health and the environment

(2) Additional information on conducting a treatment demonstration, selecting appropriate field tests, and designing test procedures for the demonstration is presented in EPA SW-874.

(3) Special requirements for ignitable or reactive wastes and for incompatible wastes are contained in 40 CFR 264.281 and 264.282. Ignitable and reactive wastes must be immediately incorporated into the soil so that they are no longer considered ignitable or reactive. They must also be protected from any material or condition that could cause ignition or reaction. Incompatible wastes, such as those listed in appendix V of 40 CFR 264, may not be placed in the same treatment zone unless precautions are taken to avoid fires, explosion and violent reactions, the generation of heat and pressure, the production of toxic mists, fumes and gas, or the creation of other conditions that might threaten human health or the environment. Federal regulations (40 CFR 264.276) also outline special requirements for application of cadmium and other hazardous wastes to lands used for growth of food-chain crops.

b. The land treatment option is limited by (1) the availability of sufficient quantities of usable land, (2) the assimilative capacity of the plant-soil system, (3) regulatory restrictions concerning food-chain crops, and (4) environmental conditions.

(1) The availability of sufficient quantities of usable land is dependent upon a number of additional limiting factors, including the application rate and regulatory requirements specifying the depth of the treatment zone.

(a) The application rate is dependent not only on the waste constituent, but also on the assimilative capacity of the soil (see EPA SW-874). While it is theoretically possible to specify land application rates and required land areas for most wastes, in practice, the complete degradation, transformation or immobilization of some constituents would require application over such large tracts of land that land treatment would not be cost-effective. Economic factors might therefore preclude land treatment of some wastes.

(b) With respect to the treatment zone, EPA regulations require that the zone which wastes are introduced be no deeper than 5 feet and that there be a 3-foot separation between the bottom of the treatment zone and the seasonal high water table. These requirements could limit land treatment in certain areas.

(2) The second factor limiting the land treatment option is the assimilative capacity of the plant-soil system to handle a particular hazardous waste; this is a complex limiting factor due to the large number of variables within the system. Among these are the physical, chemical, and biological properties of the

particular soil, the compatibility of the soil and the waste to be treated, and the capacity of the soil to receive and transmit water (hydraulic capacity). These variables are described in detail in Overcash, 1981, a definitive text on land treatment. In addition to identifying the factors limiting land treatment as a disposal option, Overcash presents detailed procedures for the design of land treatment systems for all waste types.

(3) The third limiting factor, regulatory restrictions concerning food-chain crops, is also complex. For most hazardous constituents, RCRA stipulates that there can be no uptake by food-chain crops and no greater concentration of the constituents in the crop than is found in the surrounding area. As summarized in 40 CFR 264.276, the owner/operator of a land treatment unit must demonstrate that there is no "substantial risk to human health caused by the growth of such crops in or on the treatment zone."

(a) This objective may be met either by demonstrating that hazardous constituents will not be transferred to food or feed portions of a crop, or will not occur in greater concentrations in or on identical crops grown on untreated soils under similar conditions in the same region. Both of these options require that the following be addressed: crop uptake, physical adherence to the crop, and direct ingestion of contaminated soil by grazing animals.

(b) With respect to hazardous wastes containing cadmium, even more restrictive limitations apply. If such wastes are to be land treated, the following criteria must be met:

- A pH of at least 6.5
- An application rate of no more than 0.44 lb/acres/yr
- Limits on cumulative application, as dictated by the soil's caution exchange capacity
- Special conditions for animal feed (specific details are outlined in 40 CFR 264.276)

(4) The last limiting factor, environmental conditions, actually refers to a number of natural features that restrict the siting of a land treatment unit. The precautions concerning location of landfills in karst terrain or seismic zones 3 and 4 also pertain to land treatment facilities (see para 5-2b(2)). In general, limiting environmental conditions should either be avoided or should serve as design constraints in developing the facility layout. These include:

- Hydrogeologic Conditions
  -Bedrock outcrops
  -Irregularities such as fissures or faults -Aquifer recharge zones
  -Flood-prone areas such as river flood plains
  -Wetlands
  -Karst terrain
  -Seasonally high water tables (< 4-6 ft)
  -Proximity to private or community water supply wells or reservoirs
- Climate
  -Location upwind of large populations
  -Extremely wet or cold conditions
- Topography -Steep slopes -Broken terrain
- Soils
  -Thin soil above ground-water
  -Saline soils
  -Highly permeable soils above shallow ground water
  -Soils with extreme erosion potential
- Land use -Areas formerly used for landfills
  -Areas contaminated with persistent residues from past chemical spills or waste treatment processing

c. Procedures. Land treatment is both a method of disposal and a treatment mechanism. It involves applying a waste to land and incorporating it into the soil, where it undergoes biochemical action which attenuates its negative impact on the environment. A number of techniques are available for applying the waste, depending largely on the wastewater content, but also hinging on such considerations as soil properties, topography and climate.

(1) For land application purposes, wastes are generally classified as

* Liquid (less than 8 percent solids, with particle diameters less than 1 inch)

* Semiliquid (8 to 15 percent solids and/or particle diameters greater than 1 inch)

* Solid (greater than 15 percent solids)

(2) Application of liquid wastes is generally accomplished by either spraying the waste on the land with sprinklers or by using flood or furrow irrigation techniques. Semiliquid sludges are normally applied by surface spreading, with subsequent incorporation into the soil, or by subsurface injection 4 to 8 inches below the soil surface. Low-moisture solids are spread on the surface and later incorporated into the soil (figure 5-3).

(3) Waste volatility, site terrain and weather conditions may dictate the choice of other application techniques, regardless of the water content of the waste. For example, highly volatile wastes should not be applied by irrigation or surface spreading, but be injected at least 6 inches below the soil surface. On steep slopes or in freezing weather, alternatives to spray irrigation will likewise be required. The objectives in any land treatment system, regardless of method used, are uniform application of wastes, and use of application rates within the assimilative capacity of the soil.

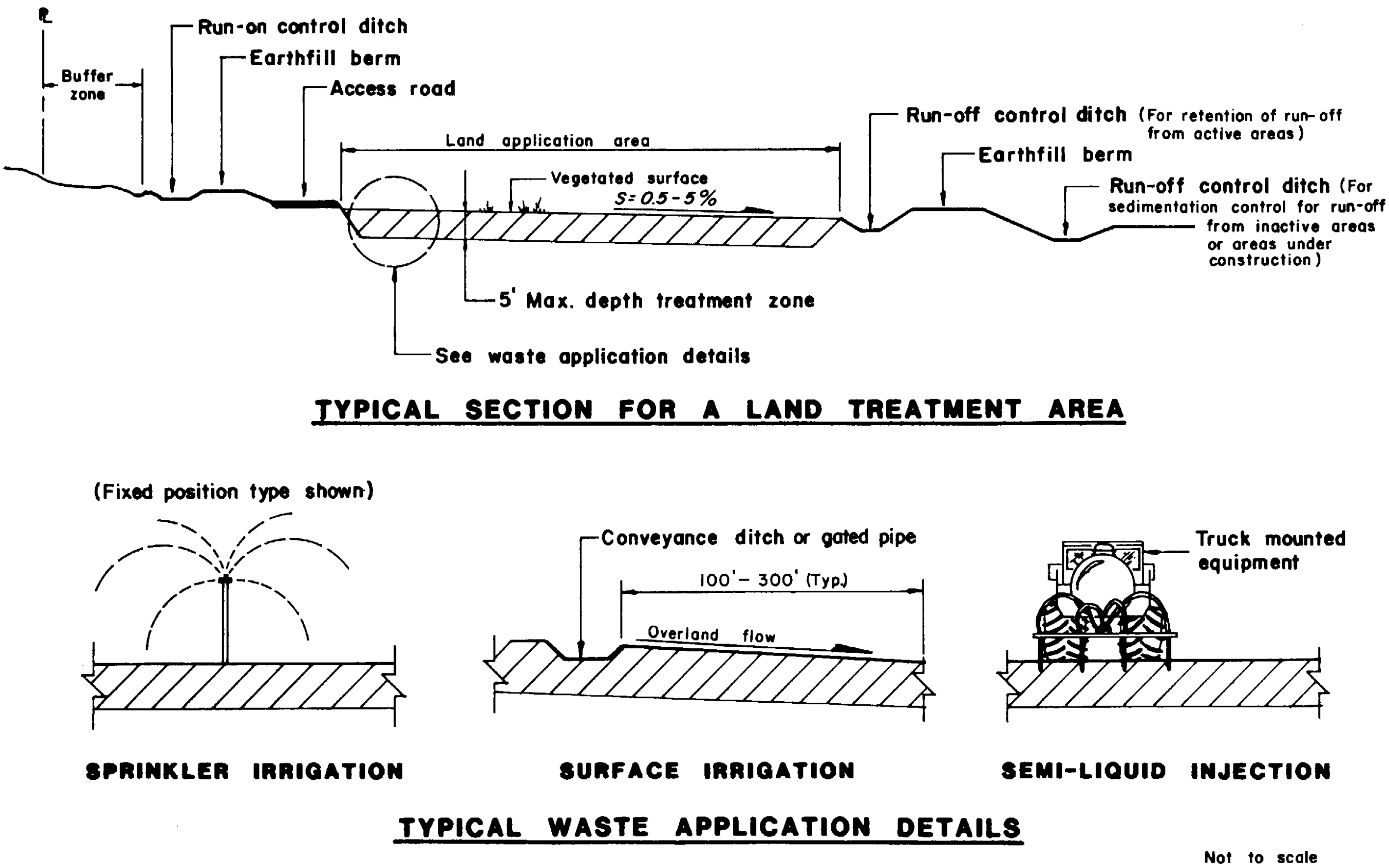

Figure 5-3. Land treatment area details.

d. Design elements. Design requirements, as well as requirements for construction, operation and maintenance, of a land treatment facility are specified in the facility permit to ensure compliance with regulations. The design goal must be to maximize the degradation, transformation or immobilization of hazardous constituents in the specified treatment zone, in accordance with all design and operating conditions used in the treatment demonstration; and minimize both runoff of hazardous constituents from the treatment area and inflow of water into the treatment area.

(1) Fulfillment of these specific design requirements, as well as meeting the principal design goal of nondegradation of the land, requires a number of steps, including analysis of the waste stream and site soil characteristics, evaluation of waste-soil interactions and site assimilative capacity, determination of application rate, selection of an application method, and layout of the facility and control structures.

(2) 40 CFR 264.278 of RCRA requires an unsaturated zone monitoring program for all land treatment units to determine whether hazardous constituents have migrated below the treatment zone. Soil and soil pore liquid must be monitored on a background plot and immediately below the treatment zone. If any migration is detected, the owner/operator of the land treatment unit must notify the EPA Regional Administration (RA) of this finding within seven days. Within 90 days the owner/operator should recommend modifications to the facility permit that will maximize treatment of hazardous constituents within the treatment zone.

(3) There are several possible configurations for a land treatment facility, including single cell, rotating cell and progressive cell configurations. In the single cell configuration a waste is applied uniformly over the required acreage without subdividing the land treatment area. In the progressive cell configuration (figure 5-3), the land treatment unit is subdivided into cells or areas which are treated sequentially, cultivated and revegetated.

(4) Adequate buffer zones should be provided between the land treatment unit and property boundaries to minimize odor problems, permit easy access to water retention facilities, and allow implementation of contingency measures to control unusual runoff.

(5) To protect ground-water, surface waters and off-site property, water management facilities must be designed and coordinated with application method and facility configuration. The amount of water which contacts treatment areas (run on) must be minimized, and run off from treated areas must be collected and treated prior to discharge, unless it is free of contamination from hazardous wastes. Two types of structures are needed: (1) diversion structures, which either intercept clean run on and divert it around the treatment area or prevent contaminated water from leaving the unit by directing it to a retention basin; and (2) run-off retention and sedimentation control basins (figure 5-4). In addition, tanks, surface impoundments, or waste piles may be needed for waste storage during inclement weather. For example, land treatment facilities in cold regions may require storage facilities, particularly if the application season is limited to spring, summer, and fall. A water balance may be performed to aid in design of such facilities. Subsurface drainage systems and leachate control and treatment systems may also be required at some hazardous waste land treatment facilities.

e. Closure. Closure of a land treatment unit may be accomplished by either establishing a permanent vegetative cover capable of maintaining growth without extensive maintenance, removing and landfilling the zone of incorporation, or capping the land treatment area to control wind and water erosion. General closure practices called for include minimizing run-off from the treatment zone, continuing ground-water monitoring, and continuing restrictions on food-chain crops. In addition, the unsaturated zone should be monitored as part of the closure procedures; however soil-pore liquid monitoring may be suspended 90 days after the last application of waste at the unit. Each of these practices is described in chapter 12 of EPA SW-874.

f. Equipment needs. Equipment required for a land treatment operation ranges from the simple to the sophisticated, depending on the application technique employed. However, all are conventional and readily available. Any equipment used for operations must be decontaminated before taking from the treatment unit

(1) For surface irrigation by furrow or flood techniques, piping and a pump are needed to transmit the waste to the point of discharge. Alternatively, a truck or trailer-mounted tank may be used to apply wastes by gravity flow or through a sprayer or manifold. Equipment needs for sprinkler systems will vary, depending on system type, but will generally require properly sized piping, pump, nozzles.

(2) A vacuum truck with flotation tires and rear sprayer or manifold may be used for surface spreading of sludge. If the sludge is too thick to be pumped, a conventional truck with moisture-proof bed may be used to dump the waste, which is then spread with a road grader or bulldozer. The blades of both road graders and bulldozers should be equipped with depth control skids and edge wings to aid in uniform application. Once the waste has been spread on the land, there are several types of equipment that can be used to incorporate the waste into the soil-moldboard plow, disk, and/or rotary tiller. Similar equipment can also be used for low-moisture solids. A spreader can also be used to apply solids which tend to be sticky or chunky.

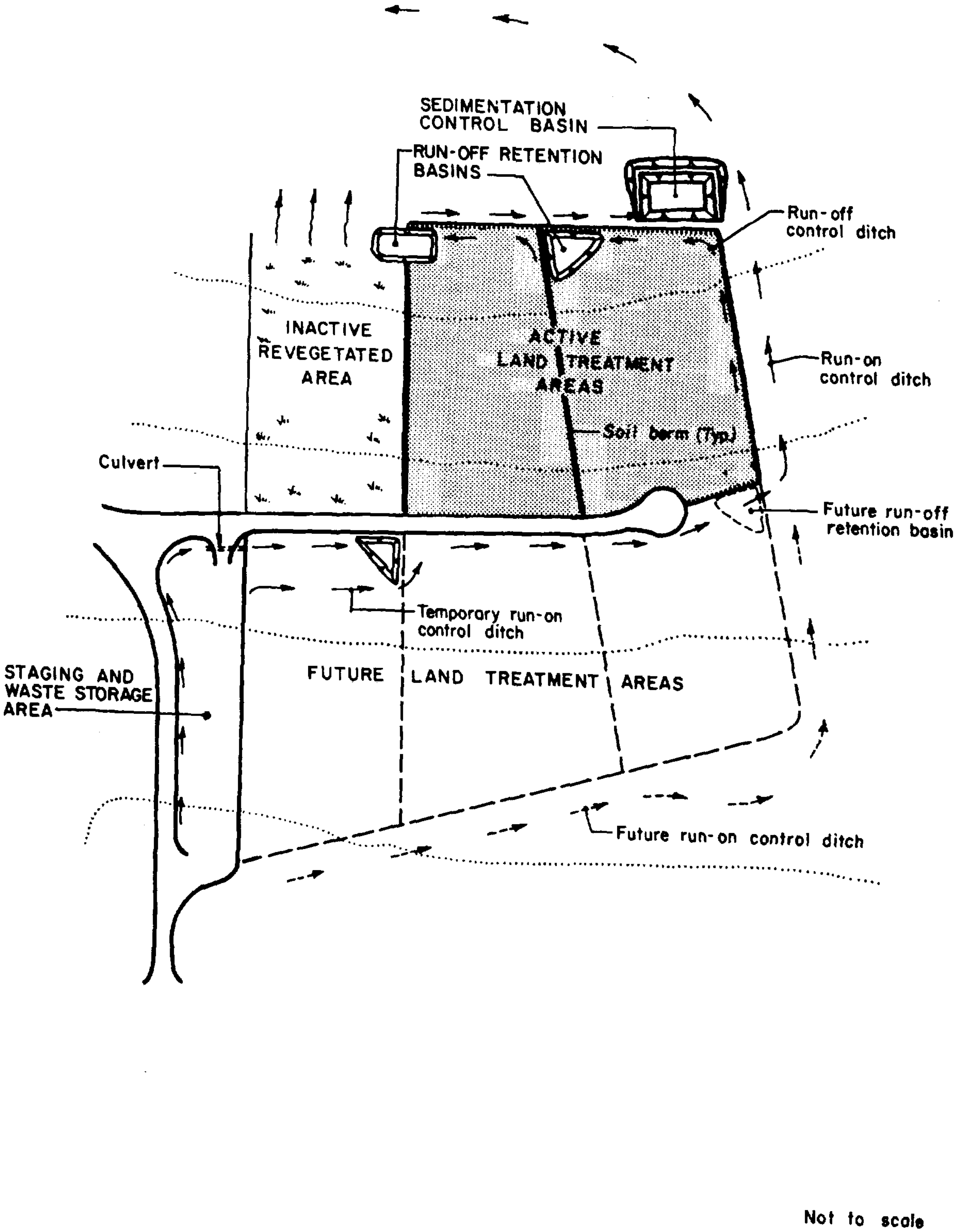

Figure 5-4. Land treatment operations plan.

(3) Basic equipment for subsurface injection of wastes consists of a truck or tractor with two or more chisels attached. Adjustable sweeps are mounted near the bottom of the chisels to open a wide but shallow underground cavity. Waste is injected into the cavity through a tube attached to the back of the chisel. For repeated application of wastes over long time periods, underground supply pipes may be installed, with flexible tubing used to connect the supply pipe to truck or tractor-mounted injectors.

5-5. Deep Well Injection

a. Suitable Wastes. Injection wells are used to dispose of large quantities of liquid hazardous wastes into the subsurface. Injection well disposal is regulated by the EPA Underground Injection Control Program (UICX40 CFR 146) and authorized by subpart C of the Safe Drinking Water Act. Currently injection wells may accept large quantities of chemical, waste-water brines or mining wastes in deep, isolated porous geological formations. Large volumes of waste, on the order of hundreds of thousands or millions of gallons, may be disposed by injection. Approximately 160 injection wells are now operating, with most used by the chemical and petrochemical industry.

(1) A wide variety of wastes can be disposed by injection. These wastes include, but are not limited to:

- Dilute or concentrated acid or alkaline solutions
- Solutions containing metals
- Inorganic solutions
- Hydrocarbons and chlorinated hydrocarbons
- Solvents
- Organic solutions with a high biochemical oxygen demand

(2) The UIC criteria and standards cover construction, operating, plugging and closure of deep wells, and monitoring and reporting requirements. The UIC classification of injection wells is as follows:

Class I	- Injects hazardous wastes as defined in 40 CFR 146, subpart A
Class II	- Injects petroleum fluids or byproducts
Class III	- Injects fluid for mineral extraction
Class IV	- Injects fluids into or above an underground drinking water source
Class V	- Injects fluids not covered in Classes I-IV

b. Disposal constraints. The injection well disposal option is limited by

- regulations and policy
- waste types
- selective geological environment
- construction and operation expense

(1) Most importantly, injection wells are considered by EPA policy to be a 'qast resort" means of disposal. It must be demonstrated that the injected fluids will not contaminate ground-water or damage the environment, and injection is used after all other means of disposal are found unsatisfactory.

(2) In addition, types of wastes to be disposed of may limit disposal options: only liquid wastes may be disposed of in injection wells. Injected wastes are strictly covered in UIC; justification for injection must be presented and pretreatment of waste streams may be required prior to injection.

(3) To ensure their separation from drinking water aquifers, injection wells are limited to sites that are in geologically isolated environments. Extensive geologic research and field work must be done to site wells and to determine injection zone isolation. Injection horizons must be tested for waste compatibility to ensure that the wastes do not contain materials that are chemically reactive with site soils or rock. Waste constituents that could pose problems include corrosive mineral salts, acids (capable of dissolving carbonate rock), and precipitated salts. In addition, the proposed injection area should be tested for overall permeability to define the injection zone. Typical siting investigations and well developments and construction information is found in comprehensive technical documents (EPA 600/2-77-240).

(4) Another disposal limitation is the existence of unexpected subsurface problems such as pressure around the formation, induced earthquake activity and dissolution of injection zone host rock. The precautions concerning location of landfills in karst terrain or seismic zones 3 and 4 also pertain to injection wells (see para 5-2b(2)). Pressure mound formation may result in a "mound" of injected fluid that forms near the injection well hose and interferes with rates of fluid injection and ground-water flow. Low magnitude earthquake swarms may be caused by injecting fluids into deep fault zones; such a case was documented at Rocky Mountain Arsenal in the 1960's. Finally, host rock may dissolve if it is incompatible with the injected waste, thereby creating voids at depth and possible subsidence effects.

(5) Worst of the subsurface problems is aquifer contamination as a result of injection. Contamination could occur as a result of incompletely plugged abandoned injection wells, displacement of saline water into potable water, or well bore failure.

(6) Finally, the substantial costs of implementing injection well disposal systems are a significant limiting factor; these systems require much professional expertise in site evaluation, testing, construction and waste stream analysis. Furthermore, the system requires stringent monitoring and maintenance to ensure good operation. Costs for typical Class I-EI type

wells may easily range into the hundreds of thousands of dollars.

c. Procedures. Wastes are disposed in injection wells by injecting waste under pressure to porous injection zones. Following their collection, wastes may be pretreated and then sent into the pressurized system. Injection may proceed round the clock, so that large volumes may be disposed of continuously. The injection well system consists of a cased and sealed borehole containing the injection tube; wastes are forced through the tube to the injection zone. Use of a tube for injection helps reduce the possibility of leaks; a tube may be replaced easily, saving wear on borehole casings (see figure 5-5). All phases of injection are monitored for leakage detection and proper operation. Disposal operations are reported quarterly, so corrective action or adjustments to the system may be made if necessary.

d. Design elements. UIC regulations require all aspects of injection well systems to be reported and classified, including construction requirements that pertain to casing type and cement type, well dimensions, waste characteristics, corrosiveness and leak prevention. The regulations also call for tests and logs, including electric logs on the injection zone formation and integrity of completed wells. In addition, midcourse evaluation of well performance is required for the first two years of operation. In general, all types of materials and procedures must be specifically described or referenced. As an example, steel and concrete corrosion resistance to the waste stream must be demonstrated.

e. Equipment needs. Injection well siting and construction requires specialized equipment, material and professional expertise. Well siting requires an exhaustive review of geology and in-situ formation testing. Injection wells are commonly 1,000 to 5,000 feet deep; therefore, drilling equipment is needed that is capable of reaching that depth. Once the geologic environment has been defined, waste compatibility studies and construction material selection may commence.

(1) Since hazardous and corrosive material will be injected, construction materials must be selected that can handle the waste stream. Concrete mixes and steel casing are chosen for their ability to ensure delivery of waste to the injection zone. Pumps and injection casing are also chosen to handle wastes and maintain injection pressure. The object of design and material selection is to choose non-reactive, non-corrosive material to deliver and isolate wastes in the injection zone only.

(2) Finally, waste pretreatment may be necessary prior to injection. One or more types of wastes may be injected, so the size and function of the facility may vary. Such a surface facility would include impound ments, filters, clarifiers, sludge collection, pH control and several injection pumps.

5-6. Waste Piles

a. Suitable Wastes. Waste pile storage and treatment is suitable for semi-solid and solid hazardous wastes such as mine tailings. Waste piles may not be used to intentionally dispose of wastes; if disposal is required, the owner/operator must obtain a landfill permit and manage the pile as a landfill. The regulatory standards for management of waste piles requires that the owner or operator take precautions in treating or storing ignitable, reactive or incompatible waste so that it does not ignite or explode, emit toxic gases, damage the contaminant structure or through other like means threaten human health or the environment. Section 264.256 prohibits the placement of ignitable or reactive wastes in a waste pile, unless the waste is made non-ignitable or non-reactive. Reactive wastes may be especially difficult to manage since waste piles are directly exposed to the environment. Incompatible wastes may not be placed on the same waste pile (section 264.257) to ensure prevention of fires, explosions, gaseous emissions, leaching, or other discharge which could result from the contact or mixing of incompatible wastes or materials.

b. Disposal constraints. Waste piles are not an ultimate disposal method; they are intended only for storage or treatment of certain solid hazardous wastes. Given this restriction, the siting criteria for this disposal method are somewhat less stringent that those for landfills or surface impoundments. In general, however, it is preferable that waste piles be located in a hydrogeologic setting that offers sufficient vertical separation of wastes from the uppermost groundwater, and low permeability soils providing the hydraulic separation. The precautions concerning location of landfills in karst terrain or seismic zones 3 and 4 also pertain to waste piles (see para 5-2b(2)).

c. Procedures. As noted above, a waste pile is any non-containerized accumulation of solid hazardous waste collected for treatment or storage; it is not used to intentionally dispose of wastes. Procedures for depositing wastes in such a unit are therefore quite simple: wastes are trucked to the waste pile location, unloaded, and then placed on the pile.

d. Design elements. Basic design requirements for waste piles include:

- Liners with a leak detection system and monitoring wells
- Leachate collection and removal
- Run-on and run-off control
- Wind dispersal control

(1) Liners selected for a waste pile must be adequate to contain wastes until closure. Considerable

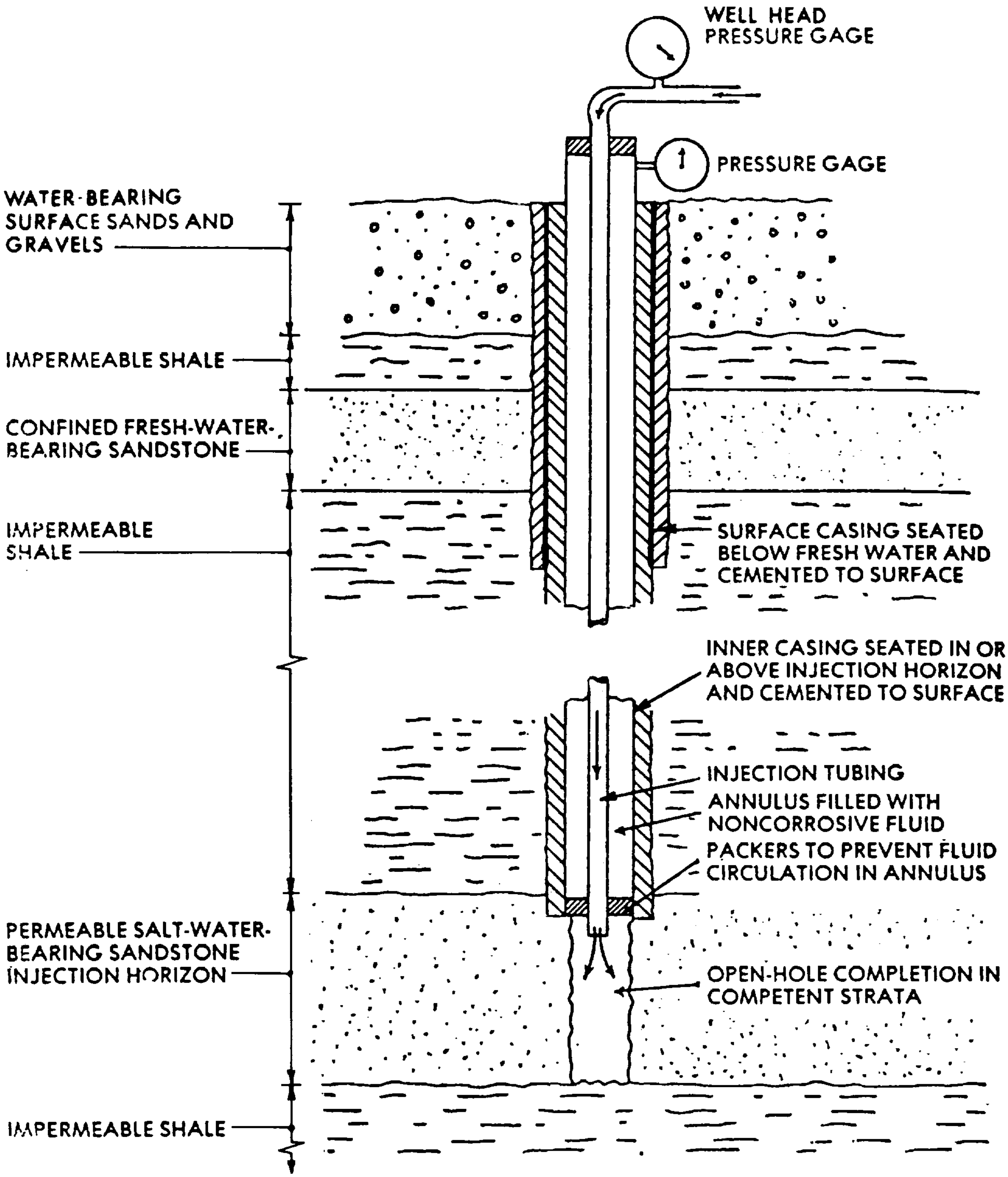

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Figure 5-5. Deep injection well.

flexibility is permitted in choice of liners, which may, for short-term storage of wastes, be constructed of clay, synthetic materials or admixes. If the waste pile will not be closed for 10 years or more (and cannot be periodically cleaned and inspected for leakage), a double-lined system with leak detection and monitoring wells is required. Details on liner requirements are presented in paragraph 6-3.

(2) A leachate collection and removal system is also required to collect any leachate that may be produced in a waste pile by infiltration of moisture, decomposition or reaction. Leachate systems are discussed in paragraph 6-4. Run-on and run-off control facilities, which are required for waste piles, are addressed in paragraph 6-5.

(3) If the waste pile contains particulate matter, wind dispersal controls are mandated by the regulations. Mechanisms for preventing dispersal of particulate are discussed under special design elements in paragraph 6-9.

e. Closure. Since waste piles cannot be used for permanent disposal of wastes, and can be permitted only for storage, closure requirements are less stringent than for disposal facilities such as landfills. The principal closure requirement for a waste pile which has achieved adequate waste containment during its active life is removal or decontamination of all waste and waste residue and all system components (e.g., liners), subsoil, structures and equipment which have been contaminated by contact with the waste. However, if contamination of the subsoil is so extensive as to preclude complete removal or decontamination, the closure and post-closure requirements applying to landfills must be observed. Ensuring adequate containment of waste should therefore be an important consideration in initial design of a waste pile.

f. Equipment needs. The type of equipment employed in operation of a waste pile depends to a large extent on the waste characteristics and the size of the pile. With the exception of compactors, many of the vehicles used in landfill operations can also be employed for waste piles. Bulldozers and front end loaders are widely used to place wastes; scrapers can also be used on some applications, particularly where the size of the pile and the coarseness of the waste permit the scraper to deposit wastes over the top of the pile. Large-scale operations may also be able to use conveyor belts or drag lines to deposit the wastes over the pile. Any equipment used to unload and place wastes must be decontaminated before being taken out of the disposal operation area.